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06 Biomolecules, Polymers and Chemistry in Everyday Life

Biomolecules

Biomolecules are chemical compounds which are building blocks of life and perform important functions in living organisms. The general biomolecules that our food contains are :

Biomolecules

- **Carbohydrates**
- **Proteins**
- **Enzymes**
- **Vitamins**
- **Nucleic acids**
- **Hormones**

1. Carbohydrate :

General formula of carbohydrate can be written as $C_x(H_2O)_y$

Here, $x = y$ or $x \neq y$

Hence these are called, Hydrates of carbon

Exceptions

- Rhamnose ($C_6H_{12}O_5$) is a carbohydrate, but it does not fit in this formula.
- Acetic acid (CH_3COOH) is not a carbohydrate, but it fits in this formula.

Simplest ratio ⟶ C : H : O

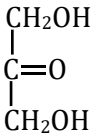
1 : 2 : 1

1. Glucose ⟶ Mol. Formula ($C_6H_{12}O_6$)
   Glucose ⟶ $C_6(H_2O)_6$
2. Sucrose ⟶ Mol. Formula ($C_{12}H_{22}O_{11}$)
   Sucrose ⟶ $C_{12}(H_2O)_{11}$

New definition of carbohydrates

Optically active polyhydroxy aldehydes and polyhydroxy ketones or compounds which give such compounds on hydrolysis are called carbohydrates.

Only dihydroxy acetone is optically inactive carbohydrate.



Carbohydrates are also called saccharides (greek word: saccharon means sugar).

Classification of Saccharides on the basis of behaviour on hydrolysis :-

- **Monosaccharides**
- **Oligosaccharides**
- **Polysaccharides**

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Monosaccharides

- A carbohydrate that cannot be hydrolysed further to give simpler unit of polyhydroxy aldehyde or ketone is called a monosaccharide.
- About 20 monosaccharides are known to occur in nature.

Example: glucose, fructose, ribose, etc.

Monosaccharides are further classified on the basis of number of carbon atoms and the functional group present in them. If a monosaccharide contains an aldehyde group, it is known as an aldose and if it contains a keto group, it is known as a ketose. Number of carbon atoms constituting the monosaccharide is also introduced in the name as is evident from the examples given in table.

No. of Carbon Atoms	Aldose (these contain aldehyde functional group)	Ketose (these contain ketone functional group)
3	Aldotriose = Glyceraldehyde	Ketotriose = Dihydroxy ketone
4	Aldotetrose = Erythrose	Ketotetrose = Erythrulose
5	Aldopentose = Ribose	Ketopentose = Ribulose
6	Aldohexose = Glucose	Ketohexose = Fructose
7	Aldoheptose = Manohaptose	Ketoheptose = Sedoheptulose

Oligosaccharides

- Carbohydrates that yield two to ten monosaccharide units on hydrolysis, are called oligosaccharides.
- They are further classified as disaccharides, trisaccharides, tetrasaccharides etc. depending upon the number of monosaccharides which provide on hydrolysis.

Example: sucrose (glucose + fructose), maltose (glucose + glucose) etc.

Polysaccharides

Carbohydrates which yield a large number of monosaccharide units on hydrolysis are called polysaccharides. Some common examples are starch, cellulose, glycogen, etc. Polysaccharides are not sweet in taste, hence they are also called non-sugars.

The carbohydrates may also be classified as either reducing or non-reducing sugars.

Reducing sugars

1. They reduce Fehling solution and Tollen's reagent
2. All monosaccharides & disaccharides in which aldehydic and ketonic groups are free, behave as reducing sugars.

   Example : Glucose, Fructose, Maltose & lactose.

Non-reducing sugars

1. They do not reduce Fehling's solution and Tollen's reagent.
2. All polysaccharides & disaccharides in which aldehydic or ketonic groups are bonded behave as non-reducing sugars.

   Example : Sucrose, Starch, Glycogen

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Monosaccharides

Glucose

1. Laboratory Method

From Sucrose (Cane sugar)

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{H_2SO_4 \text{ or } HCl} C_6H_{12}O_6 + C_6H_{12}O_6$$

Sucrose		Glucose	Fructose
'd'		'd'	'ℓ'
+66.5°		+52.5°	–92.4°

On hydrolysis of sucrose, the sign of rotation changes from dextro (+) to laevo (–), so sucrose is called invert sugar.

2. Commercial Method

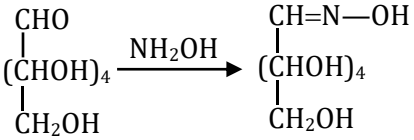
From Starch

$$(C_6H_{10}O_5)_n + H_2O \xrightarrow[393\ K;\ 2\text{-}3\ atm]{H^+} nC_6H_{12}O_6$$

Starch → Glucose

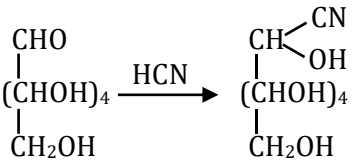
Chemical reactions of Glucose

(a) Reaction with NH_2OH



Glucose oxime

(b) Reaction with HCN

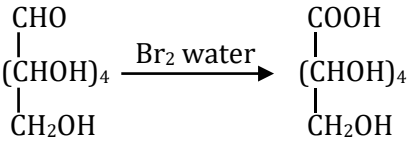


Glucose cyanohydrin

(c) Oxidation

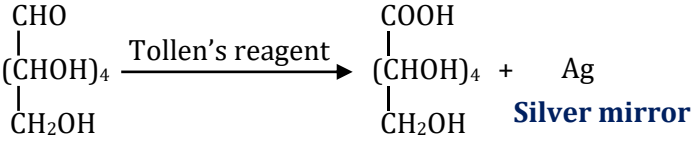
Oxidation of glucose to six carbon carboxylic acid (gluconic acid) indicates that the carbonyl group is present as an aldehydic group.

(i) Oxidation with Br_2 water



Gluconic acid

(ii) Oxidation by Tollen's Reagent, Fehling solution and Benedict's solution



Silver mirror

Gluconic acid

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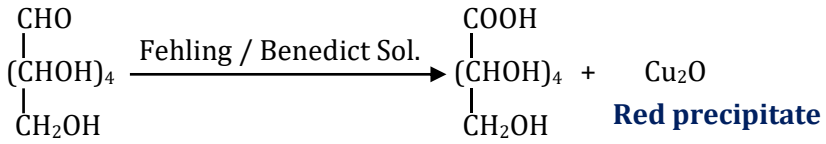
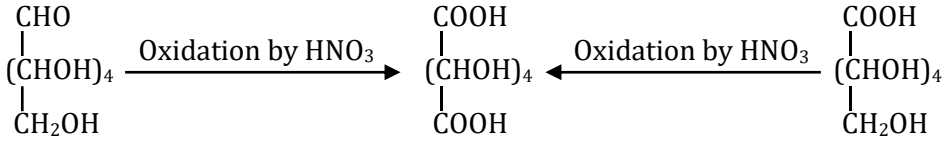


Gluconic acid

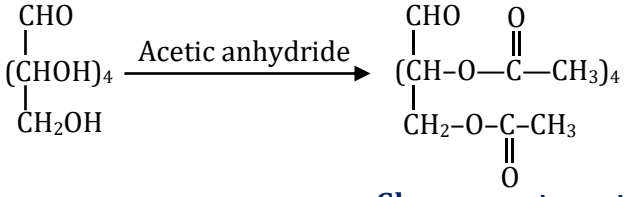
Oxidation of glucose to six carbon containing di carboxylic acid indicates the presence of primary Alcohol group.

(iii) Oxidation by conc. HNO_3



Glucose **Saccharic acid** **Gluconic acid**

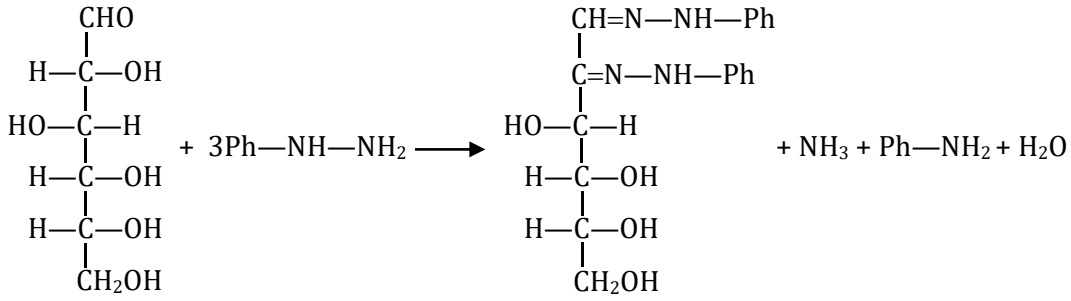
(d) Acetylation of glucose with acetic anhydride gives glucose penta acetate which confirms the presence of five –OH groups



Glucose penta acetate

(e) Reaction with Phenyl Hydrazine (Osazone formation)

When carbohydrates react with excess of phenyl hydrazine then osazone is formed



Glucosazone

Structure of Glucose

Open chain structure **Cyclic Structure**

Open chain structure of Glucose

The exact spatial arrangement of different –OH groups was given by Fischer after studying many other properties.

Glucose is correctly named as D(+)-glucose. The meaning of D– and L– notations is given as follows.

D – (+) – Glyceraldehyde **L – (–) – Glyceraldehyde**

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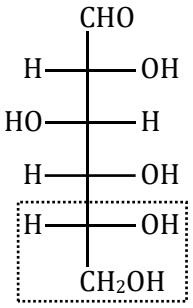
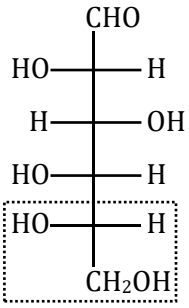
D before the name of glucose represents the configuration whereas (+) represents dextrorotatory nature of the molecule.

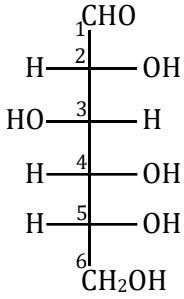


D– (+) – Glucose
[α] = + 52.7°

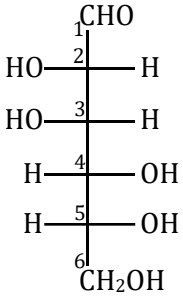


L– (–) – Glucose
[α] = – 52.7°

Epimers : Optically active diastereomers which have different configuration about one of the chiral carbon and same configuration at remaining carbon are called epimers.



D– (+) – Glucose



D– (+) – Mannose

These have different configuration only at second carbon so called as C-2 epimers.

Cyclic Structure of Glucose

1. Glucose does not give 2,4-DNP test & Schiff's test.
2. Glucose does not form addition product with $NaHSO_3$.
3. Penta acetate of glucose does not react with NH_2OH

D-Glucose is found to exist in two different crystalline forms which are named as α and β.

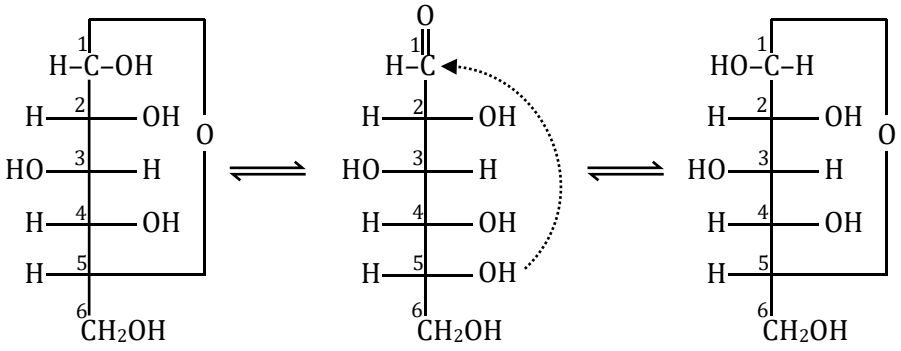
α-form: M.P. = 419 K

Obtained by crystallization of concentrated solution of glucose at 303K

β-form: M.P. = 423 K

Obtained by crystallization of concentrated solution of glucose at 371K

It was proposed that one of the –OH groups may add to the –CHO group and form a cyclic hemiacetal structure.



α – D – (+) – Glucose **β – D – (+) – Glucose**

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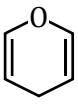
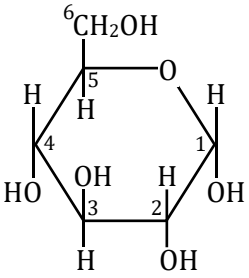
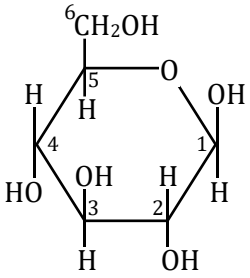
The six membered cyclic structure of glucose is called pyranose structure in analogy with Pyran.


Pyran


α – D – (+) – Glucopyranose


β – D – (+) – Glucopyranose

Haworth structure of glucose

Cyclic epimers are called anomers, so α-D-Glucose and β-D-Glucose are also called anomers which have first carbon as anomeric (hemiacetal) Carbon.

Mutarotation : α-form and β-form of D-Glucose slowly change optical rotation in aqueous solution to yield the same final rotation (α = + 52.7°), this process is known as Mutarotation. It becomes possible due to tautomerisation from cyclic hemiacetal form to acyclic form.

α – D – Glucose	⇌	D – Glucose	⇌	β – D – Glucose
36%		0.2%		63.8%

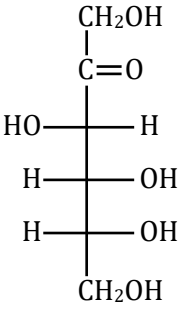
Fructose

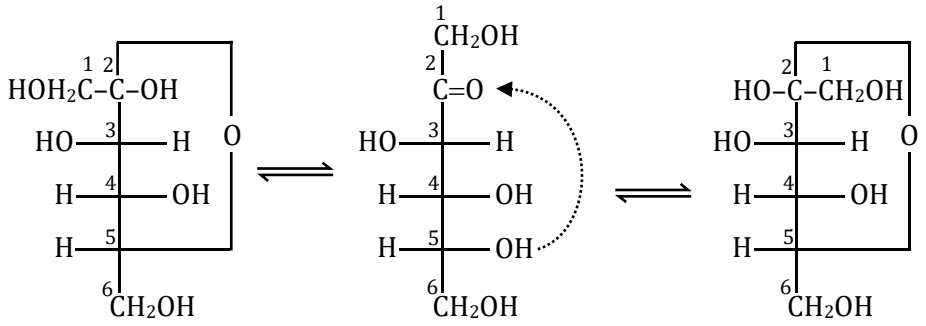
Fructose is called fruit sugar

Fructose is an important ketohexose. It is obtained along with glucose by the hydrolysis of sucrose.

Molecular formula of fructose is also $C_6H_{12}O_6$ and it belongs to D-series. It is laevorotatory compound

It also exists in two cyclic forms which are obtained by the addition of –OH at C_5 to the $>C=O$ group.


D –(–) – Fructose
[α] = –92.4°


α – D– (–) – Fructose
[α] = –21°

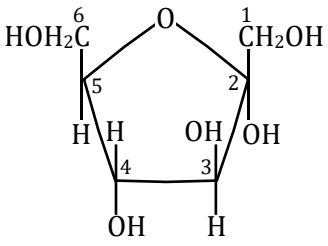
D –(–) – Fructose
[α] = –92.4°

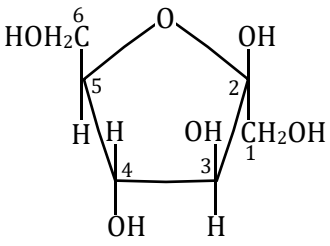
β – D– (–) – Fructose
[α] = – 133°

These differ at C_2 -Carbon so called C-2 epimers.

Cyclic structures of Fructose are also called fructofuranose structure due to analogy with furan.

Furan


α – D– (–) – Fructofuranose


β – D– (–) – Fructofuranose

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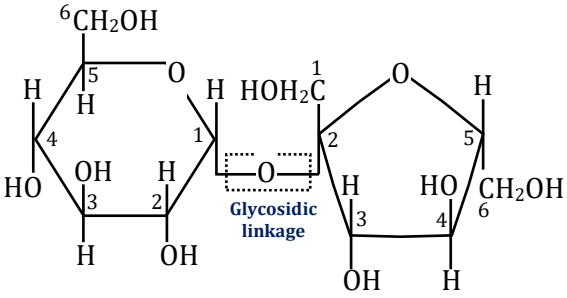
Disaccharides

(i) Sucrose : One of the common disaccharides is sucrose which on hydrolysis gives equimolar mixture of D- (+)-glucose and D-(-) fructose.

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \longrightarrow \underset{\text{D – (+) - Glucose}}{C_6H_{12}O_6} + \underset{\text{D – (-) Fructose}}{C_6H_{12}O_6}$$

These two monosaccharides are held together by a glycosidic linkage between C_1 of **α-D-glucose** and C_2 of **β-D-fructose**. Since the reducing groups of glucose and fructose are involved in glycosidic bond formation, sucrose is a non reducing sugar.

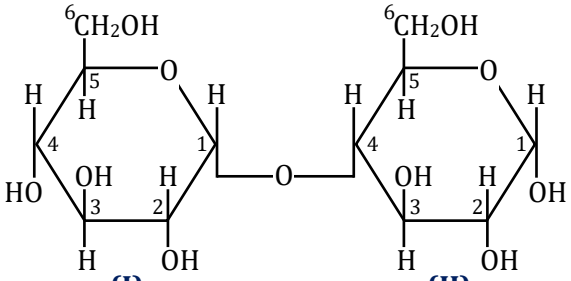
Hydrolysis of sucrose brings about a change in the sign of rotation, from dextro (+) to laevo (–) and the product is named as **invert sugar**.



α – D – Glucose β – D – Fructose

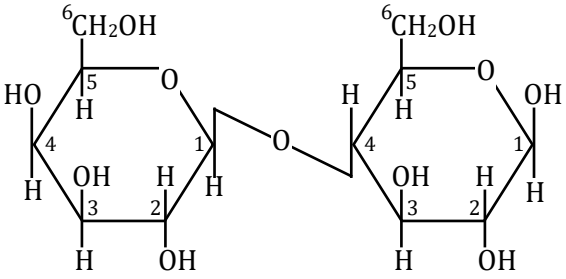
Sucrose

(ii) Maltose: Another disaccharide, maltose is composed of two **α-D-glucose** units in which C_1 of one glucose (I) is linked to C_4 of another glucose unit (II). The free aldehyde group can be produced at C_1 of second glucose in solution and it shows reducing properties so it is a reducing sugar.



(I) α – D – Glucose **Maltose** **(II)** α – D – Glucose

(iii) Lactose : It is more commonly known as milk sugar since this disaccharide is found in milk. It is composed of **β-D-galactose** and **β-D-glucose**. The linkage is between C_1 of galactose and C_4 of glucose. It is also a reducing sugar.



β – D – Galactose β – D – Glucose

Lactose

Polysaccharides

(i) Starch: Starch is the main storage polysaccharide of plants. It is the most important dietary source for human beings. High content of starch is found in cereals, roots, tubers and some vegetables. It is a polymer of α-glucose and consists of two components—

Amylose and Amylopectin :

Amylose is hot water soluble component which constitutes about 15-20% of starch. Chemically amylose is a long unbranched chain with 200-1000 α-D-(+)-glucose units held by C_1– C_4 glycosidic linkage.

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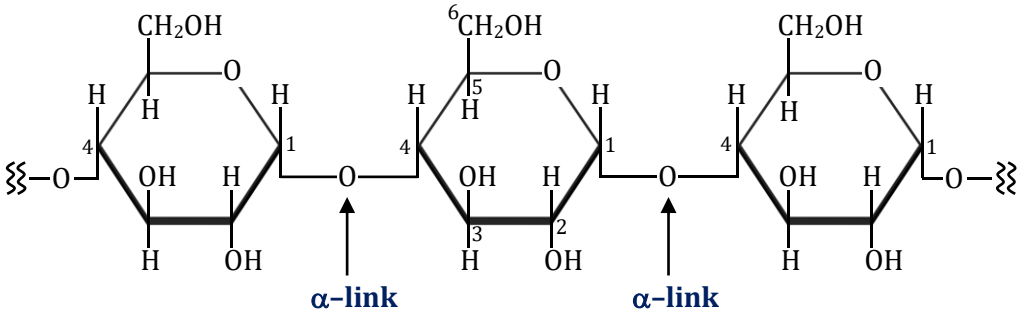
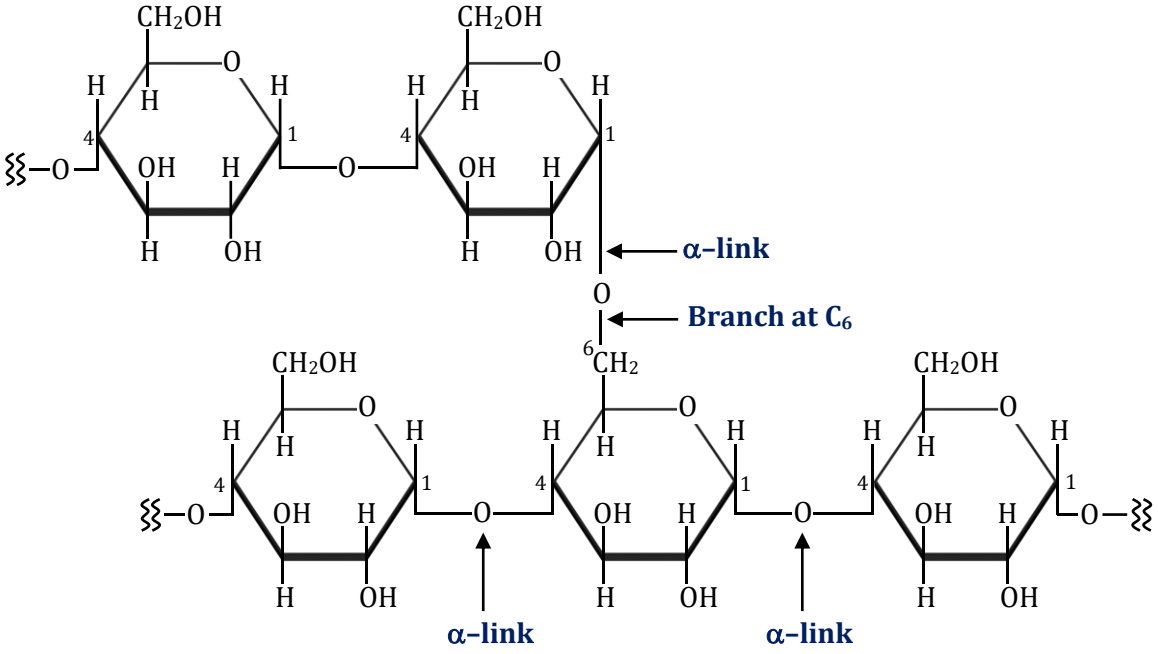
Amylopectin is insoluble in water and constitutes about 80-85% of starch. It is a branched chain polymer of α-D-glucose units in which chain is formed by C_1–C_4 glycosidic linkage whereas branching occurs by C_1–C_6 glycosidic linkage.



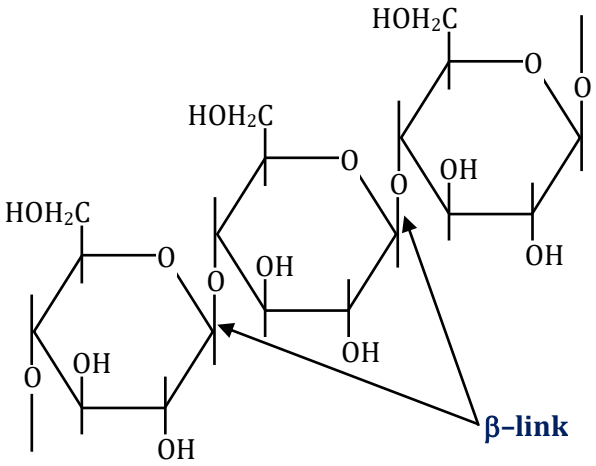
Amylose



Amylopectin

(ii) **Glycogen :** The carbohydrates are stored in animal body as glycogen. It is also known as animal starch because its structure is similar to amylopectin and is rather more highly branched. It is present in liver, muscles and brain. When the body needs glucose, enzymes break the glycogen down to glucose. Glycogen is also found in yeast and fungi.

(iii) **Cellulose :** Cellulose occurs exclusively in plants and it is the most abundant organic substance in plant kingdom. It is a predominant constituent of cell wall of plant cells. Cellulose is a straight chain polysaccharide composed only of β-D-glucose units which are joined by glycosidic linkage between C_1 of one glucose unit and C_4 of the next glucose unit.



Cellulose

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BEGINNER'S BOX-1

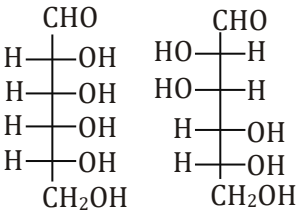
1. Glucose can be tested by following –
(1) Tollen's reagent (2) Fehling's solution
(3) Both of these (4) None of these

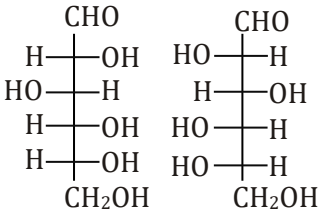
2. Glucose on oxidation with nitric acid as well as gluconic acid both gives –
(1) Saccharic acid (2) n-Hexane (3) Fructose (4) Glucosazone

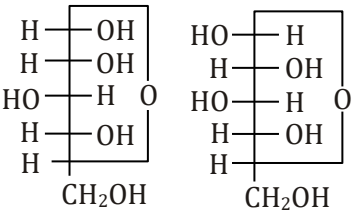
3. The spontaneous change in specific rotation of an optically active compound is called –
(1) Mutarotation (2) Rearrangements (3) Inversion (4) Retention

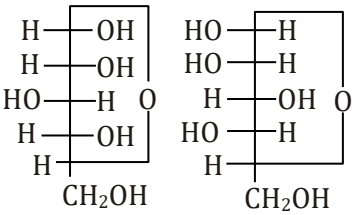
4. Hydrolysis of sucrose brings about a change in sign of rotation from dextro(+) to laevo(–) and such a sign change is known as –
(1) Racemization (2) Inversion (3) Mutarotation (4) None of these

5. Which of the following pairs represents anomer:-

(1) 

(2) 

(3) 

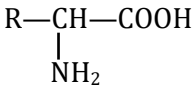
(4) 

Proteins

The word protein is derived from Greek word, "proteios" which means primary or of prime importance. All proteins are polymers of α-L-amino acids.

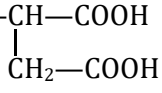
Amino acids: Amino acids contain amino (–NH_2) and carboxyl (–COOH) functional groups. Depending upon the relative position of amino group with respect to carboxyl group, the amino acids can be classified as α, β, γ, δ and so on. Only α-amino acids are obtained on hydrolysis of proteins. They may contain other functional groups also.

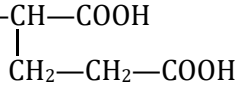
Classification of α-Amino acids
1. Acidic amino acids
2. Basic amino acids
3. Neutral amino acids



α-amino acid

1. **Acidic amino acids:-** Number of acidic group > Number of basic groups

1. Aspartic acid [Asp] :- 

2. Glutamic acid [Glu] :- 

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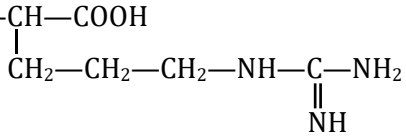
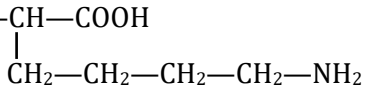
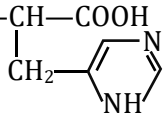
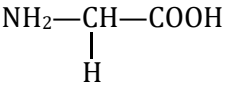
2. **Basic amino acids:-** Number of basic groups > Number of acidic groups

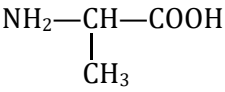
1. Arginine [Arg] :- 

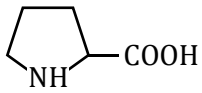
2. Lysine [Lys] :- 

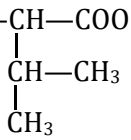
3. Histidine [His] :- 

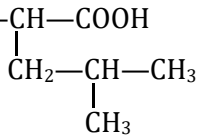
3. **Neutral amino acids:-** Number of acidic groups = Number of basic groups

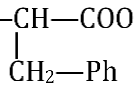
1. Glycine [Gly] :- 

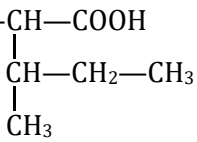
2. Alanine [Ala] :- 

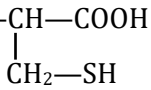
3. Proline [Pro] :- 

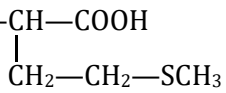
4. Valine [Val] :- 

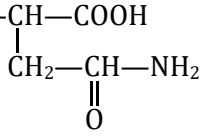
5. Leucine [Leu] :- 

6. Phenyl alanine [Phe] :- 

7. Isoleucine [Ile] :- 

8. Cysteine [Cys] :- 

9. Methionine [Met] :- 

10. Asparagine [Asn] :- 

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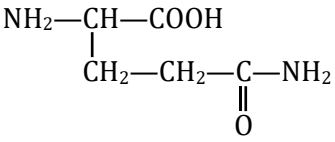
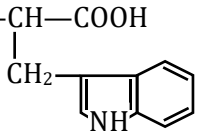
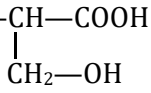
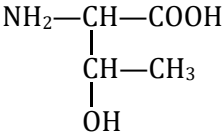
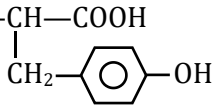
11. Glutamine [Gln] :- 

12. Tryptophan [Trp] :- 

13. Serine [Ser] :- 

14. Threonine [Thr] :- 

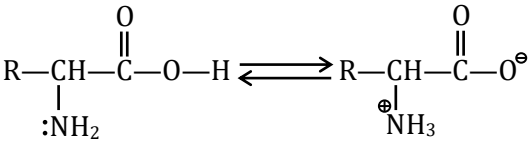
15. Tyrosine [Tyr] :- 

Classification of Amino Acids :

Amino acids are classified as acidic, basic or neutral depending upon the relative number of amino and carboxyl groups in their molecule.

The amino acids, which can be synthesised in the body, are known as non-essential amino acids. On the other hand, those which cannot be synthesised in the body and must be obtained through diet, are known as essential amino acids.

Amino acids are usually colourless, crystalline solids. These are water-soluble, high melting solids and behave like salts rather than simple amines or carboxylic acids. This behaviour is due to the presence of both acidic (carboxyl group) and basic (amino group) groups in the same molecule.



(Zwitter ion)

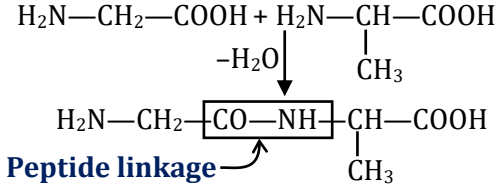
In aqueous solution, the carboxyl group can lose a proton and amino group can accept a proton, giving rise to a dipolar ion known as zwitter ion. This is neutral but contains both positive and negative charges.

In zwitter ionic form, amino acids show amphoteric behaviour as they react both with acids and bases.

Except glycine, all other naturally occurring α-amino acids are optically active, since the α-carbon atom is asymmetric. These exist both in 'D' and 'L' forms. Most naturally occurring amino acids have L-configuration. L-Aminoacids are represented by writing the $-NH_2$ group on left hand side.

Structure of Proteins :

Proteins are the polymers of α-amino acids and they are connected to each other by peptide bond or peptide linkage. Chemically, peptide linkage is an amide formed between $-COOH$ group and $-NH_2$ group.



Glycylalanine [Gly-Ala]

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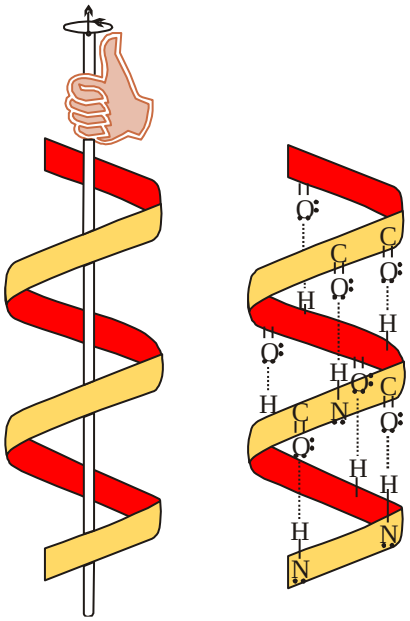
The reaction between two molecules of similar or different amino acids, proceeds through the combination of the amino group of one molecule with the carboxyl group of the other. This results in the elimination of a water molecule and formation of a peptide bond –CO–NH–.

Proteins can be classified into two types on the basis of their molecular shape.

(a) Fibrous proteins

When the polypeptide chains run parallel and are held together by hydrogen and disulphide bonds, then fibre- like structure is formed. Such proteins are generally insoluble in water. Some common examples are keratin (present in hair, wool, silk) and myosin (present in muscles), etc.



(b) Globular proteins

This structure results when the chains of polypeptides coil around to give a spherical shape. These are usually soluble in water. Insulin and albumins are the common examples of globular proteins.

Structure and shape of proteins can be studied at four different levels, i.e., primary, secondary, tertiary and quaternary, each level being more complex than the previous one.

1. Primary structure of Proteins:

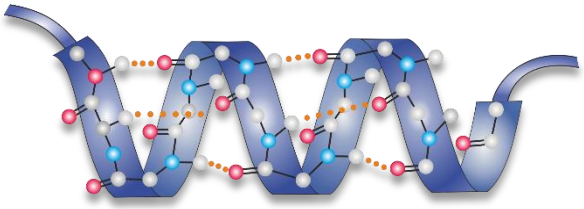
The primary structure of proteins refers to the sequence of amino acids held together by peptide bonds.

Any change in this sequence of amino acids creates a different protein.

Primary structure

2. Secondary structure of Proteins:

(i) α-Helix structure :- In α-helix a polypeptide chain forms all possible hydrogen bonds by twisting into right-handed screw



α–helix

Secondary structure

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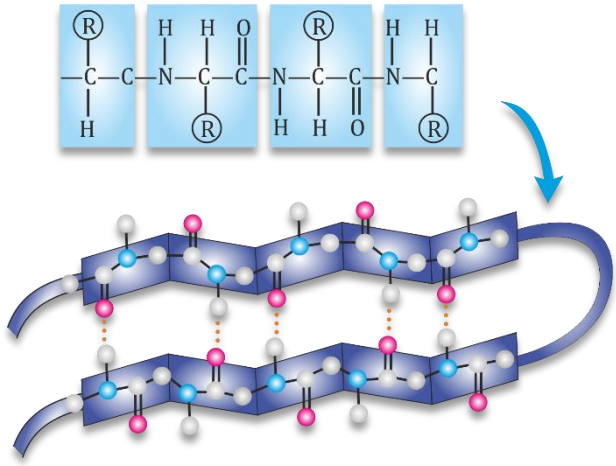
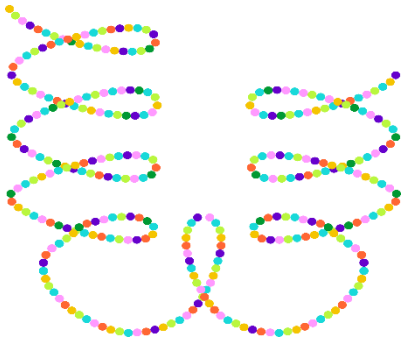
(ii) β - pleated sheet structure :- In β- structure all peptide chains are stretched out to nearly maximum extension and then laid side by side which are held together by inter molecular hydrogen bonds.



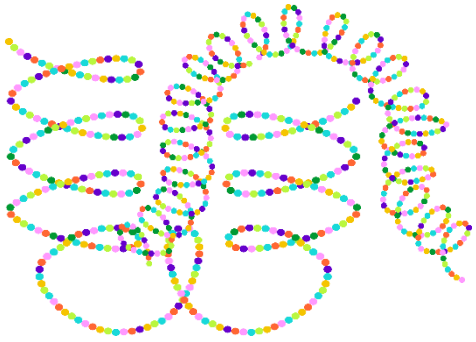
3. Tertiary structure of Proteins:

The tertiary structure of proteins represents overall folding of the peptide chains. It gives rise to two molecular shapes fibrous and globular.



Tertiary structure

4. Quaternary structure of Proteins:



Quaternary structure

Some of the proteins are composed of two or more polypeptide chains referred to as sub-units. The special arrangement of these subunits with respect to each other is known as quaternary structure.

Denaturation of Proteins :

Physical change like change in temperature or chemical change like change in pH, the hydrogen bonds are disturbed. Due to this, globules unfold and helix get uncoiled and protein loses its biological activity. This is called denaturation of protein.

The coagulation of egg white on boiling is a common example of denaturation. Another example is curdling of milk which is caused due to the formation of lactic acid by the bacteria present in milk.
During denaturation, secondary and tertiary structures are destroyed but primary structure remains unchanged.

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Enzymes

- Enzymes are biological catalysts which bring about chemical reactions in living cells. They are produced by the living organism and are usually present in only very small amounts in the various cells.
- Enzymes are very specific for a particular reaction and for a particular substrate.
- All enzymes are globular proteins.
  Examples: Pepsin, Trypsin, Proteases etc.

Vitamins

The organic compounds required in the diet in small amounts to perform specific biological functions for normal maintenance of optimum growth and health of the organism are called vitamins.

1. Fat soluble vitamins : **A**, **D**, **E** and **K**
2. Water soluble vitamins : **B** and **C**

S.N.	Vitamin	Chemical name	Deficiency disease	Source
1	Vitamin-A	**Retinol**	**Xerophthalmia** (Hardening of cornea of eye) and Night blindness	Fish liver oil, Carrot, Butter, Milk
2	Vitamin-B_1	**Thiamine**	**Beri-beri** (Loss of appetite and retarded growth), Paralysis	Yeast, Milk, Green vegetables, Cereals
3	Vitamin-B_2	**Riboflavin**	**Cheilosis** (Fissuring at corners of mouth and lips)	Milk, Egg white, Liver, Kidney
4	Vitamin-B_6	**Pyridoxine**	**Convulsion**	Milk, Yeast, Egg yolk, Cereals
5	Vitamin B_{12}	**Cyanocobalamine**	**Pernicious anaemia** (RBC deficient in Hb)	Fish, Meat, Egg, curd
6	Vitamin-C	**Ascorbic acid**	**Scurvy** (bleeding gums)	Citrus fruits, Amla Green leafy vegetables
7	Vitamin-D	**Calciferol**	**Rickets** (Bone deformities in children) **Osteomalacia** (soft bones & joint pain in adults)	Exposure to sunlight, Fish, Egg yolk
8	Vitamin-E	**Tocoferol**	Increased fragility of RBC Muscular weakness	Vegetable oil, Sunflower oil
9	Vitamin-K	**Phylloquinone**	**Increased blood clotting time**	Green leafy vegetables

Nucleic Acids

It has been observed that nucleus of a living cell is responsible for the transmission of inherent characters, also called heredity. The particles in nucleus of the cell, responsible for heredity, are called chromosomes which are made up of proteins and another type of biomolecules called nucleic acids.

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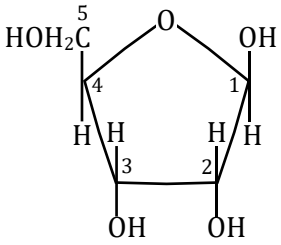
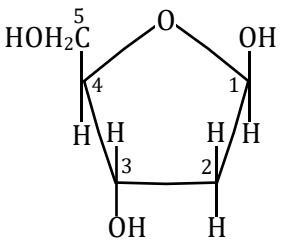
These are mainly of two types, the deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). Since nucleic acids are long chain polymers of nucleotides, so they are also called polynucleotides.

1. Chemical composition of Nucleic Acids :

Complete hydrolysis of DNA (or RNA) yields a pentose sugar, phosphoric acid and nitrogen containing heterocyclic compounds (called bases). In DNA molecules, the sugar moiety is β-D-2-deoxyribose whereas in RNA molecule, it is β-D-ribose.

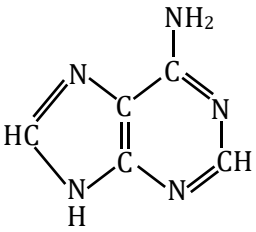


β–D–ribose

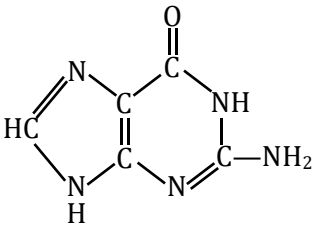


β–D–2–deoxyribose

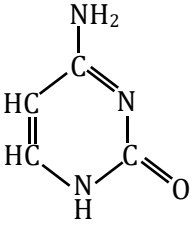
DNA contains four bases viz. adenine (A), guanine (G), cytosine (C) and thymine (T). RNA also contains four bases, the first three bases are same as in DNA but the fourth one is uracil (U).



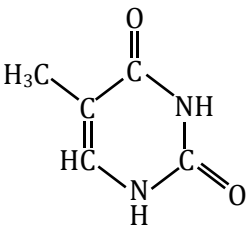
Adenine (A)



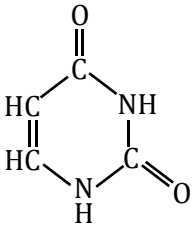
Guanine (G)



Cytosine (C)



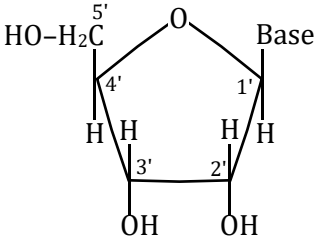
Thymine (T)



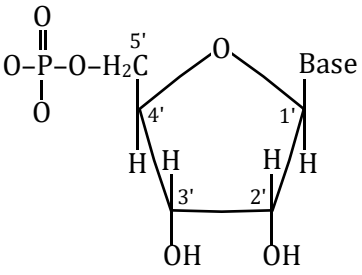
Uracil (U)

2. Structure of Nucleic Acids :-

A unit formed by the attachment of a base to 1' position of sugar is known as nucleoside. In nucleosides, the sugar carbons are numbered as 1', 2', 3', etc. in order to distinguish these from the bases. When nucleoside is linked to phosphoric acid at 5'-position of sugar moiety, we get a nucleotide.



(a)



(b)

Structure of (a) a nucleoside and (b) a nucleotide

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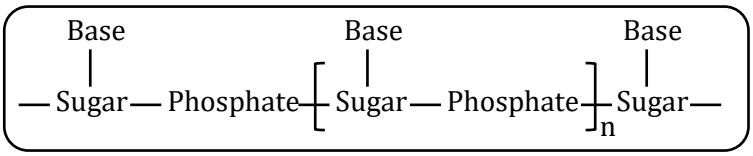
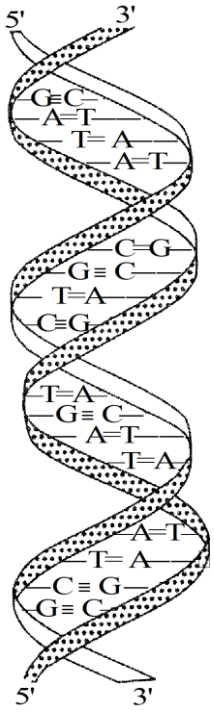
Nucleotides are joined together by phosphodiester linkage between 5' and 3' carbon atoms of the pentose sugar. A simplified version of nucleic acid chain is as shown below. Fig.



Information regarding the sequence of nucleotides in the chain of a nucleic acid is called its primary structure. Nucleic acids have a secondary structure also.

James Watson and Francis Crick gave a double strand helix structure for DNA (Fig.). Two nucleic acid chains are wound about each other and held together by hydrogen bonds between pairs of bases. The two strands are complementary to each other because the hydrogen bonds are formed between specific pairs of bases.

Adenine forms hydrogen bonds with thymine whereas cytosine forms hydrogen bonds with guanine.
In secondary structure of RNA, helix are present which are only single stranded. Sometimes they fold back on themselves to form a double helix structure.



Double strand helix structure for DNA

RNA molecules are of three types and they perform different functions.

1. messenger RNA (m-RNA)

2. ribosomal RNA (r-RNA)

3. transfer RNA (t-RNA).

Hormones

Hormones are biomolecules which are produced in the ductless (endocrine) glands and are carried to different parts of the body by the blood stream where they control various metabolic processes. These are required in minute quantites and unlike fats and carbohydrates these are not stored in the body but are continuously produced.
Some important hormones along with the sources and functions are summarised below :

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Name	Organ of secretion	Functions
(I) Steroidal hormones		
(A) Sex hormones		
(a) Androgens (Testosterone)	Testes	Control the development and normal functioning of Androsterone and male sex organs.
(b) Estrogens (Estrone, Estradiol, Estriol)	Ovary	Control the development and normal functioning of female sex organs.
(c) Gestogens (Progesterone)	Corpus luteum	Control the development and maintenance of pregnancy.
(B) Adrenal cortex hormones or corticoids (Cortisone, Corticosterone Aldosterone etc.)	Adrenal cortex	Regulate the metabolism of fats, proteins and carbohydrates; control the balance of water and minerals in the body.
(II) Peptide hormones		
(i) Oxytocin	Posterior pituitary gland	Controls the contraction of the uterus after child birth and releases milk from the mammary glands.
(ii) Vasopressin	Posterior pituitary gland	Controls the reabsorption of water in the kidney.
(iii) Angiotensin II	Blood plasma of persons with high blood pressure.	Potent vasoconstrictor i.e. contracts the blood vessels.
(iv) Insulin	Pancreas	Controls the metabolism of glucose, maintains glucose level in the blood.
(III) Amine hormones		
(i) Adrenaline or Epinephrine	Adrenal medulla	It is an amine compound and was the first hormone to be isolated. Prepares animals and humans for emergency in many ways by raising the pulse rate, blood pressure etc. stimulates the breakdown of liver glycogen into blood glucose and fats into fatty acids during emergency. These properties make adrenaline as one of the most valuable drugs used in medicine.
(ii) Thryoxine	Thyroid gland	Controls metabolism of carbohydrates, lipids and proteins.

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BEGINNER'S BOX-2

1. Zwitter ion is –
(1) Neutral ion (2) Positive charge ion
(3) Negative ion (4) None of these

2. In β-sheet of proteins, conformers are held together by (Secondary structure of protein) –
(1) Intermolecular H-bond (2) Intramolecular H-bond
(3) Conformers not held together (4) None of these

3. DNA contains following purines bases –
(a) Adenine (b) Guanine (c) Thymine (d) Cytosine
(1) a, c (2) a, b (3) a, c, d (4) a, b, c, d

4. Which of the following statement is/are true –
(1) DNA has deoxyribose while RNA has ribose sugar
(2) DNA contains thymine while RNA has uracil
(3) Both of these
(4) None of these

5. RNA on translation gives –
(1) Protein (2) DNA (3) Both (4) None of these

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Polymers

Polymer is defined as a high molecular weight compound formed by the combination of a large number of one or more types of small molecules (Monomers).

Classification of Polymers

Polymers are classified in following ways:

1. Classification based upon source

(a) Natural polymers

Polymers which are obtained from animals and plants are known as natural polymers. Examples of natural polymers are given below.

Natural polymer	Monomers
1. Polysaccharide	Monosaccharide
2. Proteins	α-L-Amino acids
3. Nucleic acid	Nucleotide
4. Natural Rubber (*cis*-1,4-polyisoprene)	Isoprene (2-Methyl-1,3-butadiene)

(b) Semisynthetic polymers

Polymers which are derived from natural polymers are known as semisynthetic polymers. Most of the semisynthetic polymers are prepared from cellulose. Examples are: cellulose acetate (rayon), cellulose nitrate, cellulose xanthate etc.

(c) Synthetic polymers

Man-made polymers, i.e. polymers prepared in laboratory are known as synthetic polymers. Example are : PVC, polyethylene, polystyrene, nylon 6, nylon 6,6 , nylon 6,10 , terylene, synthetic rubbers etc.

2. Classification based upon structure

(a) Linear polymers

Polymer whose structure is linear is known as linear polymer. The various linear polymeric chains are stacked over one another to give a well packed structure.

The chains are highly ordered with respect to one another. The structure is close packed in nature, due to which they have high densities, high melting point and high tensile (pulling) strength.

(b) Branched chain polymers

Branched chain polymers are those in which the monomeric units constitute a branched chain. Due to the presence of branches, these polymers do not pack well. As a result branched chain polymers have lower melting points, low densities and tensile strength as compared to linear polymers.

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Branched chain polymers may be formed due to addition as well as condensation polymerisation. Examples are low density polyethylene (LDP).

(c) Cross-linked or three dimensional network polymers

In these polymers the initially formed linear polymeric chains are joined together to form a three dimensional network structure. These polymers are hard, rigid and brittle. Cross-linked polymers are always condensation polymers. Resins are cross linked polymers, Urea-formaldehyde resin, phenolformaldehyde resin.

3. Based on mode of polymerisation

(i) Addition polymer : (Chain growth polymerisation)

Addition polymers retain all the atoms of the monomer units in the polymer. Addition polymerisation takes place in three steps. Initiation, chain propagation and chain termination. Addition polymers are called as chain growth polymers.

Polymers which are formed by addition reaction are known as addition polymers. If monomer is ethylene or its derivative, then addition polymer is either linear polymer or branch- chain polymer.

Examples are: polystyrene, polytetrafluoroethylene, polyacrylonitrile etc.

Types :

(a) Homopolymers: Addition polymers formed by the polymerisation of a single monomeric species.

Ex : (i) $n CH_2=CH_2 \rightarrow \underset{\text{Polythene}}{\{CH_2-CH_2\}_n}$

Ethene

(ii) $n CH_2=CHCl \longrightarrow \underset{\text{Polyvinyl chloride (PVC)}}{\{CH_2-\underset{Cl}{\underset{|}{CH}}\}_n}$

Vinyl chloride

(iii) $n CH_2=CHCN \longrightarrow \underset{\text{Polyacrylonitrile (orlon or acrilan) (PAN)}}{\{CH_2-\underset{CN}{\underset{|}{CH}}\}_n}$

Acrylonitrile

(iv) $n CF_2=CF_2 \rightarrow \underset{\text{Teflon (used in making oil seals and also used for non-stick surface coated utensils)}}{\{CF_2-CF_2\}_n}$

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(b) **Copolymers:** Addition polymers formed by the polymerisation of two different monomers.

Ex : (i) $nCH_2=CH-CH=CH_2 + nC_6H_5CH=CH_2 \longrightarrow -\left(CH_2-CH=CH-CH_2-\underset{\displaystyle C_6H_5}{\underset{|}{CH}}-CH_2\right)-_n$

1,3-Butadiene **Styrene** **Butadiene styrene copolymer (Buna-S)**

(ii) $nCH_2=CH-CH=CH_2 + nCH_2=\underset{\displaystyle CN}{\underset{|}{CH}} \longrightarrow -\left(CH_2-CH=CH-CH_2-CH_2-\underset{\displaystyle CN}{\underset{|}{CH}}\right)-_n$

1,3-Butadiene **Acrylonitrile** **Butadiene acrylonitrile copolymer (Buna-N)**

Mechanism of Addition Polymerisation

A variety of alkenes or dienes and their derivatives are polymerised in the presence of a free radical generating initiator (catalyst) like benzoyl peroxide, acetyl peroxide, tert-butyl peroxide, etc. For example, the polymerisation of ethene to polythene consists of heating or exposing to light with a small amount of benzoyl peroxide initiator.

Chain initiating steps

$$C_6H_5-\overset{\displaystyle O}{\overset{\|}{C}}-O-O-\overset{\displaystyle O}{\overset{\|}{C}}-C_6H_5 \longrightarrow 2C_6H_5-\overset{\displaystyle O}{\overset{\|}{C}}-O^{\bullet} \longrightarrow 2C_6H_5^{\bullet}$$

Benzoyl peroxide **Phenyl radical**

$$C_6H_5^{\bullet} + CH_2=CH_2 \longrightarrow C_6H_5-CH_2-CH_2^{\bullet}$$

Chain propagating steps

$$C_6H_5-CH_2-CH_2^{\bullet} + CH_2=CH_2 \longrightarrow C_6H_5-CH_2-CH_2-CH_2-CH_2^{\bullet} \longrightarrow C_6H_5-\left(CH_2-CH_2\right)_nCH_2-CH_2^{\bullet}$$

Chain terminating step

For termination of the long chain, these free radicals can combine in different ways to form polythene. One mode of termination of chain is shown as under:

$$\begin{matrix} C_6H_5-\left(CH_2-CH_2\right)_nCH_2-CH_2^{\bullet} \\ + \\ C_6H_5-\left(CH_2-CH_2\right)_nCH_2-CH_2^{\bullet} \end{matrix} \longrightarrow C_6H_5-\left(CH_2-CH_2\right)_nCH_2-CH_2-CH_2-\left(CH_2-CH_2\right)_nC_6H_5$$

4. Preparation of some important polymers

(i) Polythene

There are two types of polythene as given below:

(a) **Low density polythene:** It is obtained by the polymerisation of ethene under high pressure of 1000 to 2000 atmospheres at a temperature of 350 K to 570 K in the presence of traces of dioxygen or a peroxide initiator (catalyst). The low density polythene (LDP) obtained through the free radical addition and H-atom abstraction has highly branched structure.

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Low density polythene is chemically inert and tough but flexible and a poor conductor of electricity. Hence, it is used in the insulation of electricity carrying wires and manufacture of squeeze bottles, toys and flexible pipes.

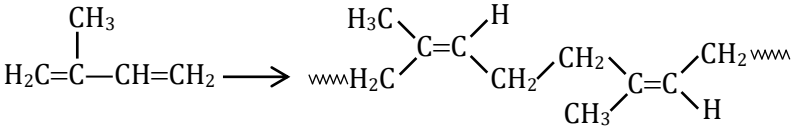
(b) **High density polythene:** It is formed when addition polymerisation of ethene takes place in a hydrocarbon solvent in the presence of a catalyst such as triethylaluminium and titanium tetrachloride (Ziegler-Natta catalyst) at a temperature of 333 K to 343 K and under a pressure of 6-7 atmospheres. High density polythene (HDP) thus produced, consists of linear molecules and has a high density due to close packing. It is also chemically inert and more tougher and harder. It is used for manufacturing buckets, dustbins, bottles, pipes, etc.

(ii) **Natural rubber**

Rubber is a natural polymer and possesses elastic properties. It is also termed as elastomer and has a variety of uses. It is manufactured from rubber latex which is a colloidal dispersion of rubber in water. This latex is obtained from the bark of rubber tree.

Natural rubber may be considered as a linear polymer of isoprene (2-methyl-1,3-butadiene) and is also called as cis-1,4-polyisoprene.

The cis-polyisoprene molecule consists of various chains held together by weak van der Waals interactions and has a coiled structure. Thus, it can be stretched like a spring and exhibits elastic properties.



Isoprene **Natural rubber**

Vulcanisation of rubber: Natural rubber becomes soft at high temperature (>335 K) and brittle at low temperatures (<283 K) and shows high water absorption capacity. It is soluble in non-polar solvents and is non-resistant to attack by oxidising agents. To improve upon these physical properties, a process of vulcanisation is carried out. This process consists of heating a mixture of raw rubber with sulphur and an appropriate additive at a temperature range between 373 K to 415 K. On vulcanisation, sulphur forms cross links at the reactive sites of double bonds and thus the rubber gets stiffened.

In the manufacture of tyre rubber, 5% of sulphur is used as a crosslinking agent.

(iii) **Synthetic rubber (Neoprene)**

Neoprene was the first synthetic rubber manufactured on large scale. Its monomer, chloroprene (2-chlorobutadiene) is prepared from acetylene.

Chloroprene (2-Chloro-1, 3-butadiene) **(Neoprene)**

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Condensation Polymers (Step Growth Polymerisation)

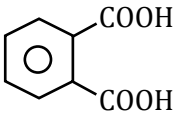
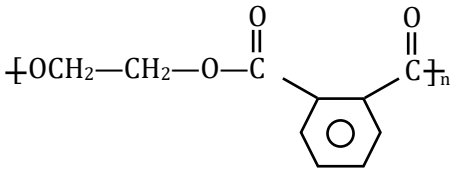
In these polymerisation reaction, the elimination of small molecules such as water, alcohol, hydrogen chloride take place.

(a) Polyester :

Ex.

(i) $nHOH_2C—CH_2OH + nHOOC-C_6H_4-COOH \longrightarrow +OCH_2—CH_2—O—C-C_6H_4-C+_n$

Ethylene glycol **Terephthalic acid** **Terylene or dacron (polyester)**

(ii) $nHOH_2C—CH_2OH +$  $\longrightarrow$ 

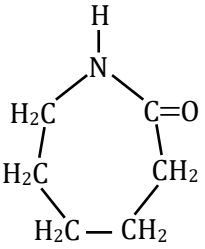
Ethylene Glycol **Phthalic acid** **Glyptal**

(b) Polyamide :

Ex.

(i) $nH_2N(CH_2)_6NH_2 + nHOOC(CH_2)_4COOH \xrightarrow[\text{High Pressure}]{553K} +NH+CH_2+_6NH—C+CH_2+_4C+_n$

hexamethylene diamine **adipic acid** **Nylon 6,6 (Polyamide)**

(ii) 

Caprolactam

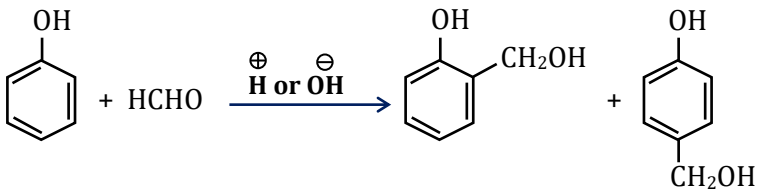
$\xrightarrow[H_2O]{533\text{-}543K}$ $+C—(CH_2)_5—N+_n$

Nylon 6

(c) Formaldehyde polymer (Bakelite and related polymers) –

(i) Bakelite :

Phenol-formaldehyde resins are obtained by the reaction of phenol and formaldehyde in the presence of either an acid or a basic catalyst. The reaction starts with the initial formation of ortho and parahydroxymethyl phenol derivatives, which further react with phenol to form compounds where rings are joined to each other with $-CH_2$ groups. The reaction involves the formation of methylene bridges in ortho, para or both ortho and para positions. Linear or cross - linked materials are obtained depending on the conditions of the reaction.



(Intermediate)
o-and p-hydroxymethyl phenol

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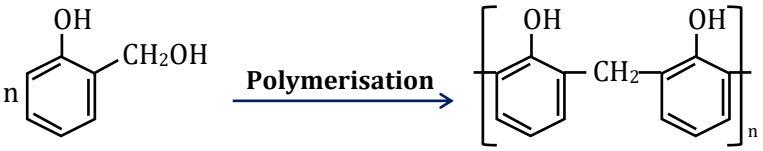
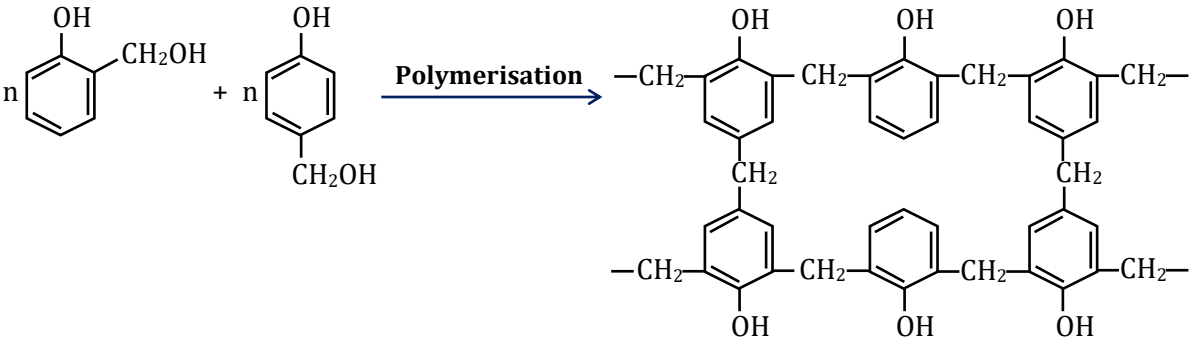


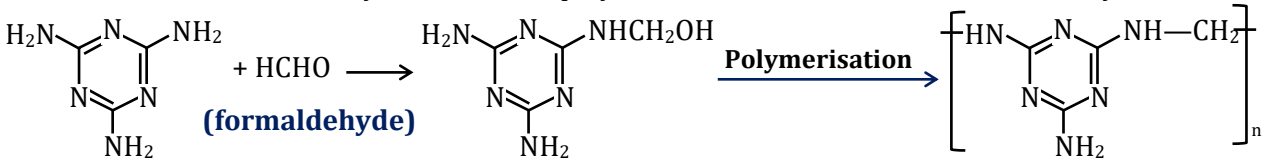
Linear polymer (Novolac)



Cross - linked polymer (Bakelite)

(ii) Melamine - formaldehyde polymer –

This resin is formed by condensation polymerisation of melamine and formaldehyde.



(Melamine) **(Intermediate)** **Melamine-formaldehyde polymer**

It is a quite hard polymer and is used in the manufacture of unbreakable crockery.

Classification of polymers based on molecular forces

A large number of polymer applications in different fields depend on their unique mechanical properties like tensile strength, elasticity, toughness, etc. These mechanical properties are governed by intermolecular forces, e.g., van der Waals forces and hydrogen bonds, present in the polymer. These forces also bind the polymer chains. Under this category, the polymers are classified into the following four sub groups on the basis of magnitude of intermolecular forces present in them.

(a) Elastomers

These are rubber – like solids with elastic properties. In these elastomeric polymers, the polymer chains are held together by the weakest intermolecular forces. These weak binding forces permit the polymer to be stretched. A few 'crosslinks' are introduced in between the chains, which help the polymer to retract to its original position after the force is released as in vulcanised rubber. The examples are buna-S, buna-N, neoprene, etc.

(b) Fibres

Fibres are the thread forming solids which possess high tensile strength and high modulus. These characteristics can be attributed to the strong intermolecular forces like hydrogen bonding. These strong forces also lead to close packing of chains and thus impart crystalline nature. The examples are polyamides (nylon 6, 6), polyesters (terylene), etc.

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(c) Thermoplastic polymers

These are the linear or slightly branched long chain molecules capable of repeatedly softening on heating and hardening on cooling. These polymers possess intermolecular forces of attraction intermediate between elastomers and fibres. Some common thermoplastics are polythene, polystyrene, polyvinyls, etc.

(d) Thermosetting polymers

These polymers are cross linked or heavily branched molecules, which on heating undergo extensive cross linking in moulds and again become infusible. These cannot be reused. Some common examples are bakelite, urea-formaldelyde resins, etc.

Note: Correct order for Intermolecular forces in various classes of polymers.
Thermosetting > Fibres > Thermoplastic > Elastomers.

Difference between thermoplastic and thermosetting polymers

S.No.	Thermoplastic polymers	Thermosetting polymers
1.	Soften and melt on heating and become hard on cooling i.e. process is reversible	Become hard on heating and process is irreversible.
2.	Can be moulded and remoulded and reshaped.	They can be moulded once and cannot be remoulded or reshaped.
3.	They are addition polymers	They are condensation polymers.
4.	Structure is generally linear	Structure is cross - linked.

Biodegradable Polymers

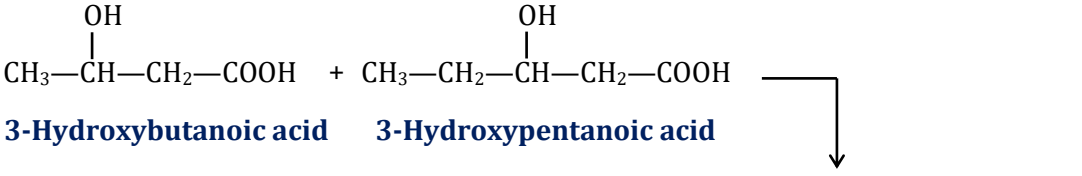
Introduction

A large number of polymers are quite resistant to the environmental degradation processes and are thus responsible for the accumulation of polymeric solid waste materials. These solid wastes cause acute environmental problems and remain undegraded for quite a long time. In view of the general awareness and concern for the problems created by the polymeric solid wastes, certain new biodegradable synthetic polymers have been designed and developed. These polymers contain functional groups similar to the functional groups present in biopolymers.

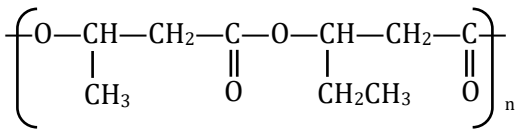
Examples :

(i) Poly β-hydroxybutyrate-co-β-hydroxy valerate (PHBV)

It is obtained by the copolymerisation of 3-hydroxybutanoic acid and 3- hydroxypentanoic acid. PHBV is used in speciality packaging, orthopaedic devices and in controlled release of drugs. PHBV undergoes bacterial degradation in the environment.



3-Hydroxybutanoic acid **3-Hydroxypentanoic acid**



PHBV

(ii) Nylon 2-nylon 6

It is an alternating polyamide copolymer of glycine ($H_2N–CH_2–COOH$) and amino caproic acid [$H_2N(CH_2)_5COOH$].

Monomers and polymers

S.N.	Monomer	Polymer	Type of Polymers
1.	$CH_2=CH_2$ (Ethylene)	Poly ethene	Addition polymer (homopolymer)
2.	$CH_2=CH-CH_3$ (Propene)	Poly propene	Addition polymer (homopolymer)
3.	$CH_2=CH-Cl$ (Vinyl chloride)	Polyvinyl chloride (PVC)	Addition polymer (homopolymer)
4.	$CH_2=CH-C_6H_5$ (Styrene)	Polystyrene	Addition polymer (homopolymer)
5.	$CH_2=CH-CN$ (Acrylonitrile)	Polyacrylonitrile (PAN) or orlon or acrilan	Addition polymer (homopolymer)
6.	$CH_2=CH-CH=CH_2$ (1,3 Butadiene) + $CH_2=CH-C_6H_5$ (Styrene)	Buna-S rubbers	Addition polymer (copolymer)
7.	$CF_2=CF_2$ (Tetrafluoroethylene)	Teflon	Addition polymer (homopolymer)
8.	$CH_2=\underset{\displaystyle CH_3}{\underset{\vert}{C}}-CH=CH_2$ (Isoprene)	Natural Rubber	Addition polymer (homopolymer)
9.	$CH_2=\underset{\displaystyle Cl}{\underset{\vert}{C}}-CH=CH_2$ (Chloroprene)	Neoprene (Artificial Rubber)	Addition homopolymer
10.	Ethylene Glycol + terephthalic acid	Terylene or Dacron (Polyester)	Condensation Copolymer, step growth
11.	Hexamethylene diamine + adipic acid	Nylon 6,6 (Polyamide)	Copolymer, step growth, linear
12.	Formaldehyde + urea	Urea formaldehyde resin	Copolymer, step growth
13.	Formaldehyde + Phenol	Bakelite	Copolymer, step growth
14.	Ethylene Glycol + Phthalic acid	Glyptal or alkyl resin	Copolymer, linear, step growth
15.	Melamine + formaldehyde	Melamine formaldehyde resin	Copolymer, step growth, thermosetting polymer
16.	Caprolactam	Nylon 6	Homopolymer, step growth

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BEGINNER'S BOX-3

1. Which of the following is a biodegradable polymer

(1) Cellulose (2) Polythene

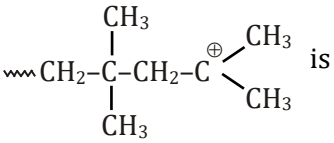
(3) Polyvinyl chloride (4) Nylon-6

2. Which one of the following is a chain growth polymer

(1) Nucleic acid (2) Polystyrene

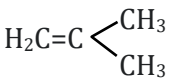
(3) Protein (4) Starch

3. The monomer of the polymer –



is

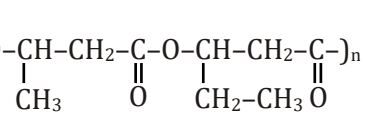
(1) $CH_3CH = CHCH_3$ (2) $CH_3CH = CH_2$

(3) $(CH_3)_2C = C(CH_3)_2$ (4) 

4. Which of the following polymer is biodegradable

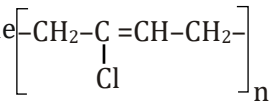
(1)

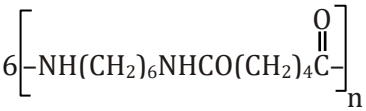
(2)

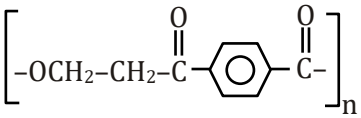
(3) 

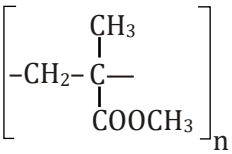
(4)

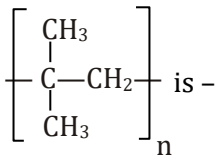
5. Which of the following is not correctly matched –

(1) Neoprene 

(2) Nylone-6, 6 

(3) Terylene 

(4) PMMA 

6. Monomer of 

is –

(1) 2–methyl propene (2) Styrene

(3) Propylene (4) Ethene

Chemistry in Everyday Life

Drugs and medicines

Chemicals in Medicines

Drugs

- Drugs are chemicals of low molecular masses (~100 – 500u).
- They interact with macro molecular targets (Proteins, lipids, carbohydrates and nucleic acids) and produce a biological response.

Medicines

- When the biological response is therapeutic and useful, these chemicals are called medicines.
- These are used in diagnosis, prevention and treatment of diseases.

Chemotherapy

- Use of chemicals (Drugs) for therapeutic effect is called chemotherapy.

Note:

Most of the drugs used as medicines are potential poisons, if taken in doses higher than those recommended.

Classification of Drugs

(a) On the basis of pharmacological effect :

Useful for doctors because it provide them the whole range of drugs available for treatment.

Example :

Analgesics ⟶ Pain killing effect.

Antiseptics ⟶ Kill or arrest the growth of microorganisms

Antifertility drugs ⟶ Birth control pills

(b) On the basis of drug action :

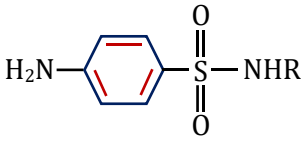
It is based on the action of a drug on a particular biochemical process.

Histamine $\xrightarrow{\text{Antihistamine}}$ Inhibit the action of the Histamine

(Causes inflammation in the body) **(Normal Body)**

(c) On the basis of chemical structure :

- Drugs which have common structure often have similar pharmacological activity.
- For example, sulphonamides have common structural feature, given below.



Structure features of sulphonamides

(d) On the basis of molecular targets :

- Drugs interact with biomolecules such as carbohydrates, lipids, drugs and nucleic acids.
- These are called target molecules or drug targets.
- Most useful classification for medicinal chemists.

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Drug-Target Interaction

- Macromolecules of biological origin perform various functions in the body.
- For example, proteins which perform the role of biological catalysts in the body are called enzymes.
- Those which are crucial to communication system in the body are called receptors.
- Carrier proteins carry polar molecules across the cell membrane.
- Nucleic acids have coded genetic information for the cell.
- Lipids and carbohydrates are structural parts of the cell membrane.

1. Enzymes as Drug Targets

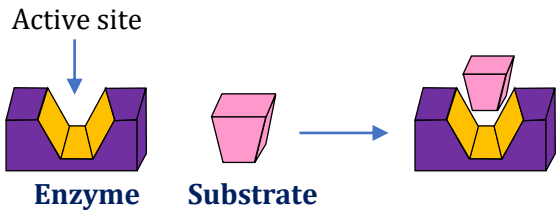
(a) Catalytic action of enzymes

Enzymes perform two major functions

(1) To hold the substrate for a chemical reaction. Active sites of enzymes hold the substrate molecule in a suitable position, so that it can be attacked by the reagent effectively.

Substrates bind to the active site of the enzyme through a variety of interactions such as **ionic bonding, hydrogen bonding, van der Waals interaction or dipole-dipole interaction.**

(2) The second function of an enzyme is to provide functional groups that will attack the substrate and carry out chemical reaction.

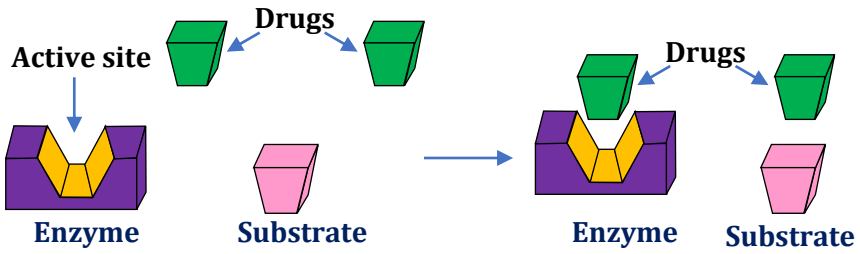


(b) Drug-enzyme interaction

Drugs can block the binding site of the enzyme and prevent the binding of substrate, or can inhibit the catalytic activity of the enzyme. Such drugs are called **enzyme inhibitors.**

Drugs inhibit the attachment of substrate on active site of enzymes in two different ways.

(1) Competitive inhibitors: Drugs compete with the natural substrate for their attachment on the active sites of enzymes.



(2) Some drugs do not bind to the enzyme's active site. These bind to a different site of enzyme which is called allosteric site.

This binding of inhibitor at allosteric site changes the shape of the active site in such a way that substrate cannot recognise it.

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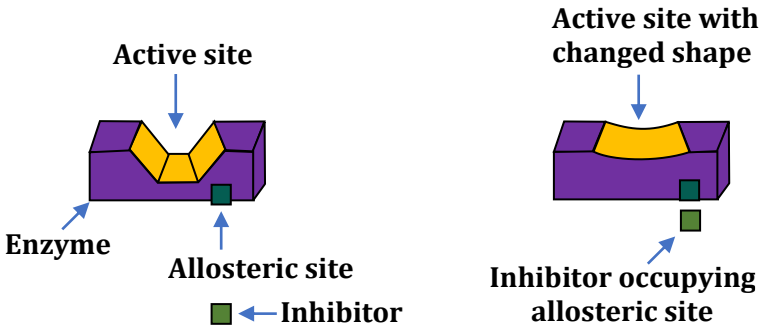
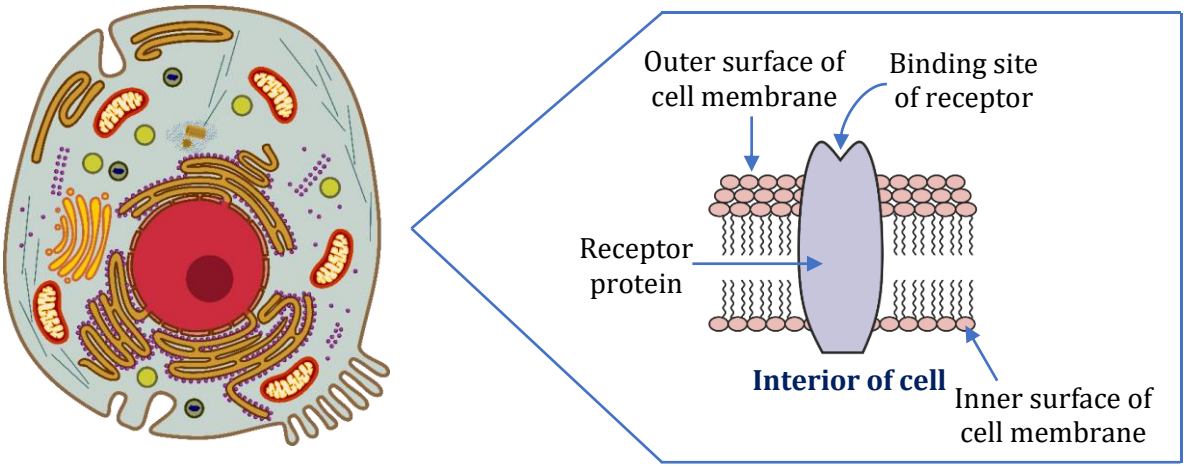


2. Receptors as drug targets

Receptors functioning

- Receptors are proteins that are crucial to body's communication process. Majority of these are embedded in cell membranes
- Active site projects out of the surface of the membrane and opens on the outside region of the cell membrane.



Chemical messengers :

- Message between two neurons and that between neurons to muscles is communicated through certain chemicals, known as chemical messengers.
- Chemical messengers are received at the binding sites of receptor proteins. To accommodate a messenger, shape of the receptor site changes.
- This brings about the transfer of message into the cell. Thus, chemical messenger gives message to the cell without entering the cell.

Antagonists :

- Drugs that bind to the receptor site and inhibit its natural function.
- These are useful when blocking of message is required.

Agonists :

- Drugs that mimic the natural messenger by switching on the receptor.
- These are useful when there is lack of natural chemical messenger.

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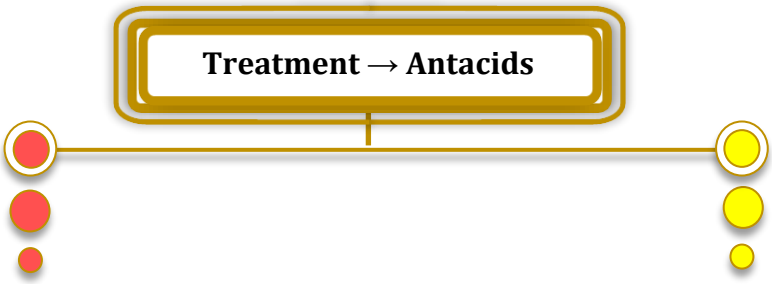
Therapeutic Action of Different Classes of Drugs

1. Antacids

- Over production of acid in stomach cause irritation and pain.
- In severe cases ulcer is developed in stomach.



Sodium Hydrogen Carbonate
$NaHCO_3$

Excess use of $NaHCO_3$ makes stomach alkaline and trigger the Production of even more acid.
These treatment control only symptoms and not the cause.

Mixture of $Al(OH)_3$ and $Mg(OH)_2$

Better alternatives because these are insoluble and hence do not increase pH above neutrality

- A chemical histamine which stimulates secretion of pepsine and HCl in stomach.
- The drug cimetidine (Tegamet) prevent the interaction of histamine with the receptor present in stomach wall. This resulted in release of lesser amount of acid
- This was largest selling drug in world, Until other drug came : **Ranitidine (Zantac)** was discovered.

2. Antihistamine

- Histamine is a potent vasodilator.
- It contracts the smooth muscles in bronchi and gut.
- It relaxes wall of blood vessels.
- It is also responsible for the nasal congestion, common cold and allergic response to pollen.

Example :

- Brompheniramine (Dimetapp, Dimetane)
- Terfenadine (Seldane)

3. Neurologically active drug

(a) Tranquilizers

- They effect the message transfer mechanism from nerve to receptor.
- They are used in treatment of stress and mental diseases.
- Essential component of sleeping pills.
- Noradrenaline (hormone) – Plays a role in mood change.
- If level of Noradrenaline is low then person suffers from depression, Antidepressant drugs are required.

Example :

Iproniazid and phenelzine are two such drugs.
Mild tranquilizer : Chlordiazepoxide and meprobamate (Relieves tension)
Equanil : used to control depression and hypertension.

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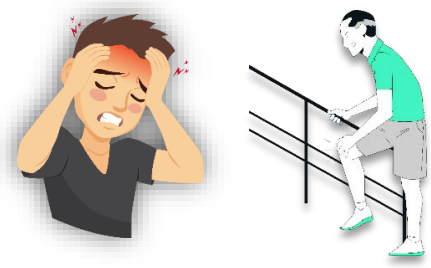
Barbiturates : Important class of tranquilizers.
Derivatives of barbituric acid are called barbiturates.
Example : Veronal, amytal, nembutal, luminal and seconal.
Barbiturates are hypnotic , i.e., sleep producing agents.

Note:
Some other substances used as tranquilizers are valium and serotonin.

(b) Analgesic - (Painkiller)
They reduce pain without causing mental confusion, unconsciousness, paralysis or other disturbances of nervous system.



(i) Non-narcotic
- Aspirin and paracetamol are non-narcotic analgesics.
- Aspirin inhibits the synthesis of chemicals known as prostaglandins which stimulate inflammation in the tissue and cause pain.
- These drugs are effective in relieving skeletal pain such as that due to arthritis.
- These drugs have many other effects such as reducing fever (antipyretic)
- Because of its anti blood clotting action, aspirin finds use in prevention of heart attacks. (Preventing platelet coagulation)

(ii) Narcotic
- Morphine and many of its homologues, when administered in medicinal doses, relieve pain and produce sleep.
- In poisonous doses, these produce stupor, coma, convulsions and ultimately death.
- Morphine narcotics are sometimes referred to as opiates, since they are obtained from the opium poppy.
- These analgesics are chiefly used for the relief of postoperative pain, cardiac pain and pains of terminal cancer, and in child birth.
- Example of Narcotic analgesics – Morphine, Heroin, Codeine

4. Antimicrobials

(a) Antibiotic
Drugs used to destroy prevent development or inhibit the pathogenic action of microbes

Bacteria	Fungi	Virus	Parasites
Antibacterial drugs	Antifungal drugs	Antiviral drugs	Antiparasitic drugs

- Used to treat infections because of their low toxicity for humans and animals.
- In 1908 Paul Ehrlich got Nobel prize for medicine for syphilis that is arsphenamine or salvarsan.

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- Salvarsan have –As = As – linkage like –N=N– linkage of Azo dyes and work selectively on germs like colour of azo dyes on tissues.
- In 1932 he also developed first effective anti bacterial agent prontosil (similar structure to salvarsan) which is convert in to compound sulphanilamide (Discovery of sulpha drugs).
- In 1929 penicillin is discover by A. Fleming from penicillium Fungus.
- Ampicillin is the modified form of penicillin.

Antibiotic have two types of effect.

(1) Cidal (killing effect)	**(2) Static (inhibitory effect)**
Bactericidal	**Bacteriostatic**
Example :	
(i) Penicillin	(i) Erythromycin
(ii) Aminoglycosides	(ii) Tetracycline
(iii) Ofloxacin	(iii) Chloramphenicol

Note:

Chloramphenicol : gives in case of typhoid dysentery, acute fever, urinary infection, meningitis, pneumonia.

Broad spectrum antibiotic :- Kill / inhibit wide range of gram positive and gram negative bacteria.

Example :

- Ampicillin
- Amoxicillin
- Chloramphenicol
- Ofloxacin
- Vancomycin

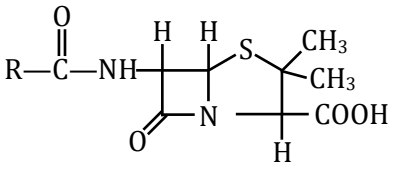
Narrow spectrum antibiotic :- Effective against gram positive or gram negative bacteria

Example :

- Penicillin G

Limited spectrum antibiotic :- Effective against a single organism or disease.

Chloramphenicol, isolated in 1947, is a broad spectrum antibiotic. It is rapidly absorbed from the gastrointestinal tract and hence can be given orally in case of typhoid, dysentery, acute fever, certain form of urinary infections, meningitis and pneumonia. The antibiotic dysidazirine is supposed to be toxic towards certain strains of cancer cells.



(Penicillin)

(b) Antiseptic and disinfectants

Antiseptic

- Chemical which either kill/prevent the growth of microorganism.
- Antiseptics are applied to living tissues such as wounds, cuts, ulcer and diseased skin surface.
  eg. : Furacine, soframicine, Dettol (mixt of chloroxylenol and terpinol)
- Bithionol (Bithional) is added to soap for antiseptic property.
- Iodine is a powerful antiseptic (2-3% of iodine in alcohol water mixture is called tincture of iodine) $\rightarrow$ applied on wounds.
- Iodoform (CHI_3) also used as antiseptic for wounds.
- Boric acid (H_3BO_3) in diluted as solution is weak antiseptic for eyes.

Disinfectants

- Applied to inanimate object (floor, drainage system, instrument).
- Same substance acts as antiseptic and disinfectant both by varying concentration.
  eg. : 0.2% phenol: Antiseptic
  1% phenol : Disinfectant
- Cl_2 in concentration of (0.2 – 0.4 ppm) in aq. solution
- SO_2 in very low concentration.

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5. Antifertility drugs

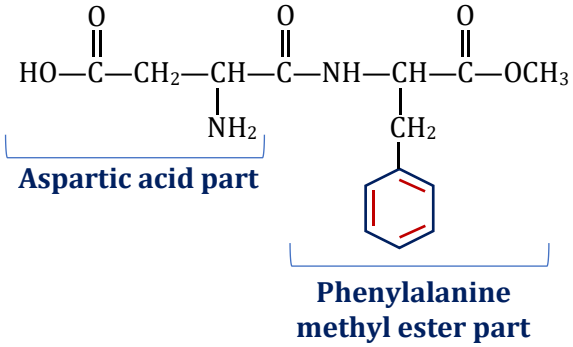
- Birth control pills contain mixture of synthesis estrogen and Progesterone derivative.
- Progesterone suppresses ovulation.
- Norethindrone (Synthetic progesterone) Widely used as antifertility drug.
- Ethynyl-estradiol (Novestrol) → Estrogen derivative.
- It is used in combination with progesterone derivative.

Food materials

Artificial Sweetening Agents

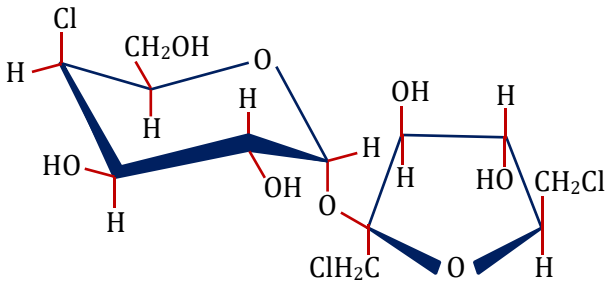
- Natural sweeteners, e.g., sucrose add to calorie intake and therefore many people prefer to use artificial sweeteners.
- Ortho-sulphobenzimide, also called saccharin, is the first popular artificial sweetening agent.
- It is about 550 times as sweet as cane sugar.
- It is excreted from the body in urine unchanged.
- It appears to be entirely inert and harmless when taken. Its use is of great value to diabetic persons and people who need to control intake of calories.

Aspartame is the most successful and widely used artificial sweetener. It is roughly 100 times as sweet as cane sugar. It is methyl ester of dipeptide formed from aspartic acid and phenylalanine. Use of aspartame is limited to cold foods and soft drinks because it is unstable at cooking temperature.



Alitame is high potency sweetener, although it is more stable than aspartame, the control of sweetness of food is difficult while using it.

Sucralose is trichloro derivative of sucrose. Its appearance and taste are like sugar. It is stable at cooking temperature. It does not provide calories.



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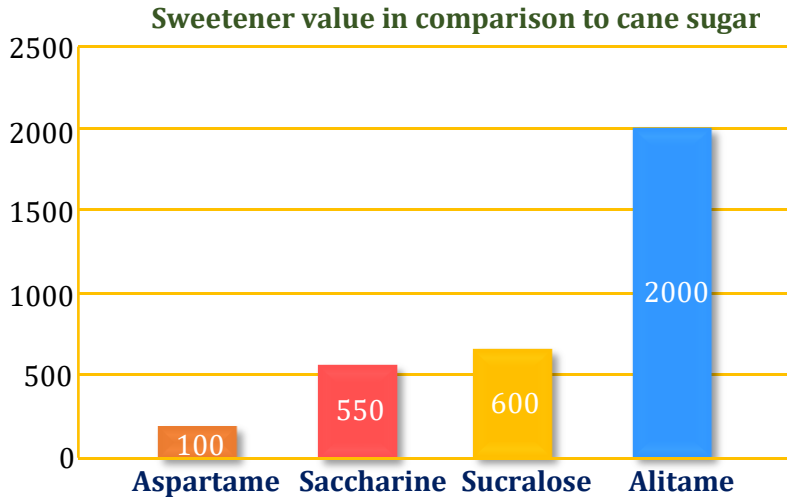

Food Preservatives

- Food preservatives prevent spoilage of food due to microbial growth.
- The most commonly used preservatives include table salt, sugar, vegetable oils and sodium benzoate (C_6H_5COONa).
- Sodium benzoate is used in limited quantities and is metabolised in the body.
- Salts of sorbic acid and propanoic acid are also used as preservatives.

Antioxidants in Food

- These help in food preservation by retarding the action of oxygen on food.
- Two most familiar antioxidants are
  (i) Butylated hydroxy toluene (BHT)
  (ii) Butylated hydroxy anisole (BHA) : Addition of BHA to butter increases its shelf life from months to years.
- Sometimes BHT and BHA along with citric acid are added to produce more effect.
- Sulphur dioxide and sulphite are useful antioxidants for wine and beer, sugar syrups and cut, peeled or dried fruits and vegetables.

Cleansing agents

In this section, we will learn about **'detergents'** ⟶ **Soaps and Synthetic detergents**
Two types of detergents are used as cleaning agents

- These improve cleansing properties of water.
- These help in removal of 'fats' which bind other material to the fabric.

Soaps

Soaps containing sodium salts are formed by heating fat (i.e., glyceryl ester of fatty acid) with aqueous sodium hydroxide solution. This reaction is known as saponification.
Only **Na** and **K** soaps are soluble in **H_2O** and are used in leasing purposes.
Generally **K** soaps are soft to the skin than **Na** soaps.

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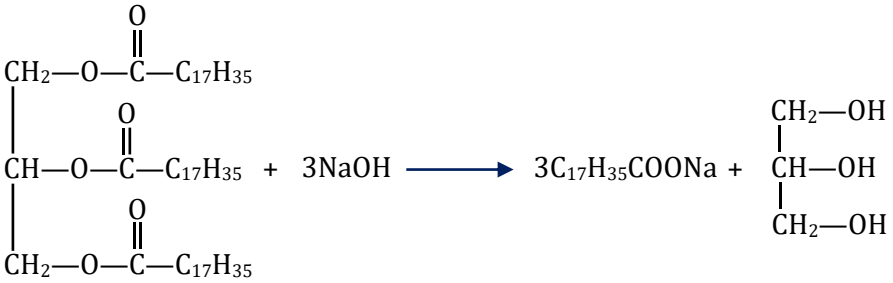


Glyceryl ester of stearic acid (Fat) | **Sodium hydroxide** | **Sodium stearate** | **Glycerol (or Glycerine)**

Why do soaps not work in hard water?

- Hard water contains calcium and magnesium ions. These ions form insoluble calcium and magnesium soaps respectively when sodium or potassium soaps are dissolved in hard water.
- These insoluble soaps separate as scum in water and are useless as cleansing agent.

Soap | **Insoluble (Soap)**

Synthetic Detergents

- Synthetic detergents used in both soft and hard water as they give foam even in hard water.
- Synthetic detergents are cleansing agents which have all the properties of soaps, but which actually do not contain any soap.
- Some of the detergents give foam even in ice cold water.

1. Anionic Detergents

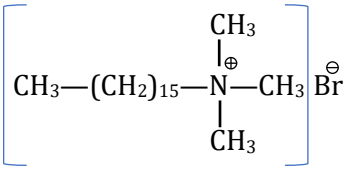
Anionic detergents are sodium salts of sulphonated long chain alcohols or hydrocarbons.

Lauryl alcohol | **Lauryl hydrogensulphate** | **Sodium laurylsulphate (anionic detergent)**

Dodecylbenzene | **Dodecylbenzenesulphonic acid** | **Sodium Dodecylbenzenesulphonate**

2. Cationic Detergents

- Cationic detergents are quarternary ammonium salts of amines with acetates, chlorides or bromides as anions.
- Cationic part possess a long hydrocarbon chain and a positive charge on nitrogen atom. Hence, these are called cationic detergents.
- Cetyltrimethylammonium bromide is a popular cationic detergent and is used in hair conditioners.
- Cationic detergents have germicidal properties and are expensive, therefore, these are of limited use.



(Cetyl trimethyl ammonium bromide)

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3. Non-ionic Detergents

- Non-ionic detergents do not contain any ion in their constitution.
- Liquid dishwashing detergents are non-ionic type.
- Mechanism of cleansing action of this type of detergents is the same as that of soaps.
- These also remove grease and oil by micelle formation.

$$CH_3(CH_2)_{16}COOH + HO(CH_2CH_2O)_nCH_2CH_2OH \xrightarrow{-H_2O} CH_3(CH_2)_{16}COO(CH_2CH_2O)_nCH_2CH_2OH$$

Stearic acid **Polyethyleneglycol**

Drawbacks

- If hydrocarbon chain is highly branched, then bacteria cannot degrade this easily.
- Slow degradation of detergents leads to their accumulation.
- These persist in water even after sewage treatment and cause foaming in rivers, ponds and streams and their water gets polluted.

Detergents with straight chain of hydrocarbons are preferred over branched chain as the latter are non-biodegradable and consequently cause environmental pollution.

BEGINNER'S BOX ANSWER KEY

BEGINNER'S BOX-1	Que.	1	2	3	4	5	
	Ans.	3	1	1	2	3	

BEGINNER'S BOX-2	Que.	1	2	3	4	5	
	Ans.	1	1	2	3	1	

BEGINNER'S BOX-3	Que.	1	2	3	4	5	6	
	Ans.	1	2	4	3	3	1	

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